

## MICROSTRUCTURED CHEMICAL SENSOR

CROSS REFERENCE TO RELATED APPLICATIONS

This application is the US national phase of PCT application PCT/DE2004/001647, filed 23 July 2004, published 10 February 2005 as WO 2005/012893, and claiming the priority of German patent application 10333996.5 itself filed 25 July 2003 and German patent application 10347415.3 itself filed 13 October 2003, whose entire disclosures are herewith incorporated by reference.

FIELD OF THE INVENTION

The invention relates to a chemical sensor with a first metallization plane arranged on a substrate and in which an electrode structure is formed, a passivation layer structured with contact holes applied to the first metallization plane and a sensitive ceramic layer which is applied to the passivation layer and in the contact holes by means of dispensing application, silk screening or ink jet processes followed by sintering.

BACKGROUND OF THE INVENTION

Chemical sensors in which the electrical resistance of a sensitive layer, usually comprised of metal oxides, can be evaluated with the aid of an evaluating structure formed by the electrodes, are known in a wide variety of configurations especially for use as gas or moisture sensors. As sensitive layers for gas detection, as a rule, porous ceramic layers, for example  $\text{SnO}_2$  or  $\text{WO}_3$  are used because their electrical surface conductivity varies with adsorption of gases. The porous ceramic layers can be

made selectively sensitive to certain gases by the use of doping agents.

The resistivity of such ceramics is very high. As a result the measurement resistance is also large. The evaluation structure, comprised usually of an interdigital structure (IDT; "Interdigitated Transducers"), may have two coplanar electrodes with fingers which interdigitate in their plane. This corresponds to parallel networks with different polarities between the two fingers across resistances which thereby have a reduced internal sensor resistance or increased sensitivity of the sensor.

Generally apart from the electrodes and the heating resistance, a temperature measurement resistance can be provided for the sensor, whereby all of the metallization elements can be structured in a single metallization plane and, for example, can be composed of platinum. To reduce the aging effect, especially of the temperature measurement resistance, in many cases a passivation layer is applied to the metallization plane, typically of silicon oxide. The passivation layer can be structured by contact holes through which contact is enabled between the electrodes and the sensitive layer applied to the passivation layer.

While the metallization and sensitive layer structures are conventionally applied to an aluminum oxide substrate, micromechanical membrane sensors are also known which use as a basis, a silicon substrate. By thermal decoupling of the sensor structure on the membrane from the substrate, the sensor can have a reduced power consumption.

A microstructured silicon membrane sensor with a sensitive layer applied to an  $\text{SiO}_2$ ,  $\text{Si}_3\text{N}_4$  membrane is known for example from DE 197 10 358 [[A1]] (US equivalent 6,787,047). With this known sensor, [[by]] in contrast [[with]] to the sensor of the invention, only the heater and temperature measurement structures are passivated with a silicon oxide layer which is applied to an interdigitated three dimensional electrode structure and in which the sensor layer is applied by a silk screen technique to fill in the electrode structure.

In general with silk-screen formation of the sensitive ceramic layer, the layer is in the form of a thick film paste which must then be sintered. The result can be mechanical stresses which may arise or remain, especially in the form of interfacial or boundary layer stresses which can result in separation of the layer material and the generation of particles. The effect of for example  $\text{SnO}_2$  or  $\text{WO}_3$  on micromechanical processes is unclear so that in general a contamination danger arises.

While the porosity of the metal-oxide ceramic which results from the sintering is desirable, on the one hand since the high sensitivity depends upon the high surface volume ratio, on the other hand the porosity has a negative effect on the mechanical stability of the layer. The most important requirement for stability is that the ceramic layer and the electrodes remain adherent to their support surfaces over the life of the sensor. Furthermore, the electrical contact between the ceramic and the electrodes should not degenerate.

Up to now, the ceramic layers have been applied directly to the passivation layer. It has been found however that the adhesion of the ceramic in many instances is insufficient.

#### OBJECT OF THE INVENTION

5 It is the object of the invention to improve the situation with respect to the adhesion.

#### SUMMARY OF THE INVENTION

10 This object is achieved in accordance with the invention with ~~[[the]]~~ a chemical sensor according to claim 1 having a bond-promoting layer configured as a second metallization plane and located between the passivation layer and the ceramic layer. ~~Further aspects and preferred features are given in the dependent claims.~~

15 The invention forms the improved chemical sensor in that an adhesion-promoting layer is provided, configured as a second metallization plane ~~which is~~ located between the passivation layer and the ceramic layer.

20 Because of the metallization applied in two layers as mentioned above it is possible to bond the porous sensitive ceramic layer better to the support for it provided by the passivation layer. Simultaneously in the upper plane between each tow contact hole openings in the metallic adhesion-promoting layer there is a locally sharply limited development of electric field lines and thus also reduced current paths between two interdigitating  
25 electrode fingers so that there is also a sharp limitation of the active zone in the sensitive ceramic which provides the advantage of improved protection against sensor poisoning , for example, by

silicon. The invention, therefore, opens up the possibility of active electrical utilization of the second metallization plane, especially but not only in association with the sensor electrodes. The adhesion-promoting layer can because of its suitability as a bond material also be utilized in the bonding region of the sensor.

Advantageously the second metallization plane is so applied that it can come to lie upon the first metallization plane in the contact holes.

It can be useful to provide a further passivation layer between the bond-promoting layer and the ceramic layer and to so structure the further passivation layer that the bond-promoting layer is partially passivated.

It can also be provided that in the electrode structure of the first metallization plane two to coplanar electrodes are structured and that the second metallization plane does not lie at a defined electrical potential. In this case the advantages include those of improved adhesion and a localization of the functional ceramic zone by equipotential surfaces.

Alternatively however it can also be provided that the electrode structure of the first metallization plane forms a first electrode and the second metallization plane is configured as a second electrode and lies at a defined electrical potential so that the sensitive ceramic layer is provided with a vertical electrode arrangement. This can result in a significantly shorter electrode spacing by comparison with conventional lithographically generated lateral spacings. On the other hand the lateral extent of the ceramic layer is no longer determined by the electrode layout

requirements and can be possibly reduced. In this connection it can be especially useful to configure the electrodes as interdigitating electrodes although all other configurations of the electrodes are also possible.

5           Advantageously in the first metallization plane, in addition to the electrode structure, a heating structure and a temperature measuring structure can be provided.

          Preferably the structures of the metallization are provided on the front side of an Si substrate which has a membrane.

#### 10                   BRIEF DESCRIPTION OF THE DRAWING

          The invention is described in greater detail in the following based upon a number of embodiments with reference to the figures of the accompanying drawing. They show:

          FIG. 1 a cross section of the sensor according to the  
15           invention;

          FIG. 2 in the same illustration, a variant of the sensor;

          FIG. 3 in the same illustration a schematic simplified detail for the cross section of FIG. 1 or FIG. 2.

#### SPECIFIC DESCRIPTION

20           FIG. 1 shows a silicon substrate 1 in which, by etching, a cavity 2 is formed in the back side of the substrate 1 to form a dielectric membrane 3 which can be comprised of a layer sequence 1 of for example silicon dioxide and silicon nitride. Above the membrane 3 there is a first metallization plane, for example of the  
25           material platinum. This metallization is so structured that the heating structure 4 and the interdigitating electrode fingers of different polarity IDT1 and IDT2 as well as, optionally, a

temperature resistance 5 for the chemical sensor are formed or configured therein. For improved adhesion of the platinum metallization of the first metallization plane, it is advantageous to convert the uppermost membrane layer, here silicon nitride, at its surface into a silicon oxide layer 3'.

Above the first metallization plane lies a passivation layer 5 (intermediate insulating layer) of for example chemical-vapor-deposited (CVD) oxide, nitride or oxynitride. In the passivation layer 6 there are holes 7 which serve to contact the ceramic layer and the bond lands. On the passivation layer 6 lies a second metallization plane, the bond-promoting layer 8, which serves to enhance the bond to and for the ceramic layer 9 and which, as described further below in connection with FIG. 3, optionally lies at a defined potential and can serve as a second interdigital electrode IDT2, whereby, in this case, the first metallization plane with respect to the evaluation structure, only shows interdigital electrode fingers IDT1 of the same polarity.

As FIG. 2 shows, the second metallization plane can be so applied that it comes to lie on the first metallization plane in the contact hole openings 7. A further passivation layer 10 can optionally lie on the second metallization 8. It contains additional holes for connection purposes.

To produce the sensor according to the invention, the raw silicon wafer is initially thermally oxidized. Then, using low pressure chemical-vapor deposition (LPCVD) LPCVD-nitride is deposited or an oxide is generated. Thereafter, on the front side of the wafer, deposition of the first metallization is carried out

and is structured into heater 4, temperature sensor 5 and interdigital electrode IDT. Then a passivation layer 6 is applied, for example a CVD oxide (chemical\_vapor deposition oxide). On the back side of the wafer an etching mask is defined for the cavity etching to produce the membrane 3. Because of the reduced thermal conductivity, the sensor is more rapidly controllable. Next the bond\_promoting layer 8 or the second metallization plane is applied, for example of one or more of the materials Au, Cr/Au, Pt, Pd, W or Sn. The bond\_promoting layer 8 is then so structured that it only remains in the region between the interdigitating electrode fingers on which the ceramic is intended to adhere and optionally should coincide with the bond lands.

On the front side of the wafer the contact holes 7 are then etched in the passivation layer 6 and for that purpose, the bond\_promoting layer 8 can function in part as an etching mask. The application of the bond\_promoting layer 8 and the etching of the contact holes can also be effected in the reverse order. Finally on the front side a protective lacquer or paint can be applied and the cavity 2 produced from the rear by anisotropic etching. In conclusion the paste dot is applied and sintered in an oven to the porous ceramic layer 9. Further details and the method steps which are known in this regard can be deduced from the above mentioned publication DE 197 10 358 [[A1]].

FIG. 3 shows in detail the cross section of the sensor in a portion thereof with the improved bond\_promoting function according to the invention. The Z dimension is drawn to a sharply larger scale for illustration purposes and the ceramic functional



layer 9 has not been illustrated for improved viewing of the parts which have been shown.

Between the two interdigital electrodes IDT1 and IDT2, a voltage is applied. The measurement signal is obtained as the current. If the upper second metallization plane which is also the structured bond-promoting layer 8 does not lie at a defined potential, that is floating, that is both IDT's are formed in the layer or the first metallization plane. Without the additional or second metallization or bond-promoting layer 8 the current path between with the IDTs would extend exclusively through the ceramic layer as represented in FIG. 3 by the broken line arrow. With the bond-promoting layer 8 according to the invention however it lies as shown between the bond-promoting layer 8 and the two IDT's.

The current path then runs outside the contact holes 7 through the bond-promoting layer 8. A change in conductivity in the periphery of the ceramic dot or the ceramic layer 9, for example as a result of ~~a poisoning~~ contamination, no longer plays any practical role in this configuration, advantageously, since the electric field lines and ths the current path are locally limited by the bond-promoting layer 8.

In case the upper second metallization plane (bond-promoting layer 8) lies at a defined potential (for example 0 volts) it can be used as IDT2. The electrode spacing in this case can be effectively half as great as with a floating bond-promoting layer 8.